# SELECTED PHYSICAL CHARACTERISTICS AND AERODYNAMIC PROPERTIES OF CHEAT SEED FOR SEPARATION FROM WHEAT

M. Hauhouot-O'Hara, B.R. Criner, G.H. Brusewitz, J.B. Solie

Dept of Biosystems and Agricultural Engineering, Oklahoma State University, Stillwater, Oklahoma, USA Tel. 405-744-8395, Fax 405-744-6059

### ABSTRACT

Cheat and similar weeds infest wheat-producing areas throughout the world. Previous solutions to cheat control such as annual applications of herbicides, moldboard plowing to bury the seeds, burning wheat stubble, or rotation of summer crops have been only partially successful and most have adverse environmental effects. An alternative approach to cheat control is mechanically damaging cheat seed during harvest to prevent reinfestation in subsequent years. To design machines to separate cheat from wheat, physical characteristics (dimensions, weight, bulk density, shape) and aerodynamic properties (terminal velocity, drag coefficient) of cheat seed were determined and compared to those reported for wheat. Although cheat seeds are similar in length to wheat they are about 50% as thick, 13% as dense, and have 40% of the terminal velocity.

**Keywords**: Cheat (*Bromus secalinus* L.), Weed control, Physical Characteristics, and Aerodynamic Properties.

<sup>1</sup> 

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

### INTRODUCTION

Cheat (*Bromus secalinus* L.) is a winter annual of the tribe Bromeae and Pooideae subfamily of the Poaceae family (Clayton and Renvoize 1986). There are more than 150 Bromus species distributed mainly in the North Temperate Zone, South America, and the mountains of the tropics (Hackel 1890; Hitchcock 1922; Tsvelev 1983, and Watson and Dallwitz 1992). Watson and Dallwitz (1992) described the use of Bromus species as weeds (*B. secalinus*, *B. arvensis*, *B. inermis*, etc.), cultivated fodder (B. *unioloides*), pasture (*B. danthoniae*, *B. carinatus*), and even crop species (*B. mango* formerly grown as a cereal in Chile). Cheat was once used in Washington and Oregon, USA, as hay (Hitchcock 1922), but now is considered as a weed in winter wheat, rye, barley and other crops. It infests winter wheat fields and can greatly reduce wheat yield.

Cheat's phenology is similar to winter wheat (Finnerty and Klingmann 1962). The caryopses of cheat germinate in the fall, grow during the winter, and flower in the spring. Figure 1 shows an open floret of cheat seed composed of two bracts: the lemma (outer bract) and palea that cover the whole caryopsis or fruit. The lemma has a bifid apex with an awn. The palea is enveloped in the lemma and tightly holds the caryopsis. The caryopsis is composed of the embryo, the endosperm (food reserve), and the scutellum that conveys hydrolyzed food reserve to embryo for plant growth. The embryo and the endosperm are enclosed within a fused pericarp and testa (Watson and Dallwitz 1992; Bradbeer 1988). The embryo is small. The endosperm is hard, without lipid, containing only simple starch grains (Watson and Dallwitz, 1992).

Cheat infestation has been a serious problem for wheat growers for many years. In Oklahoma, USA, cheat and other Bromus species infest over 1,000,000 hectares of wheat fields and can reduce the yield 50% or more. Faced with this problem, farmers and researchers have

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

tried many solutions such as applying herbicides annually, moldboard plowing to bury the seeds, burning the wheat stubble, or rotating to summer crops (Ferreira et al. 1990; Franetovich and Peeper, 1995).

Wacker (1993) described different ways to control weed seeds while harvesting. Among them are; removing non-grain components by collecting them in a trailer, adjusting settings on the combine to collect weed seeds, and destroying or reducing the viability of weed seeds by grinding or crushing in a subsequent cleaning and separation phase. Another approach being studied by researchers is to remove the weed seeds and to mechanically destroy their viability during the harvest process. Hauhouot et al. (1998) studied the feasibility of using a roller mill or a hammer mill to mechanically devitalize (reduce viability) seeds of *B. secalinus* L. Cheat seeds were crushed between the rolls with gaps varying from 0.1 mm to 1.1 mm. Seeds fed into a hammer mill were struck by hammers until they were small enough to go through the selected screen. Both mills reduced the seed viability at least 95%. Either of these machines could be mounted on a combine harvester. Damaged weed seed could be collected for animal feed or deposited on the ground with assurance that it would not germinate and cause an infestation the following year.

Physical characteristics of the seed such as dimensions, weight, shape (sphericity, aspect ratio) and bulk density are necessary to establish machine design and operating variables for the roller mill and the hammer mill. Knowing the seeds dimensions can help in selecting the optimum gap between the rolls to crush the seed and the optimum screen opening size for the hammer mill. Hauhouot-O'Hara et al.(1999) investigated the effect of hammer mill and roller mill variables on Cheat (*Bromus secalinus* L.) germination. They found that germination decreased as hammer mill shaft speed or number of hammers increased, and screen opening size

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

decreased. Germination also decreased, with increasing roll speed differential ratio and decreasing roll gap. Knowledge of properties such as the bulk density and the weight of cheat are necessary in sizing machine components and designing related equipment such as conveyors.

Rather than mechanically damaging the entire wheat-weed mixture, the weed seeds should first be separated from the wheat. Seed separation can be accomplished by using pneumatic separators, screen cleaners, or gravity tables. Many commercial cleaners incorporate more than one of these cleaning methods. To best utilize these methods, it is helpful to know the aerodynamic characteristics of both the grain and weed seed. Characteristics that dictate pneumatic separation are usually described by either terminal velocity or drag coefficient (Grochowicz, 1980). Likewise, seed shape and size are major considerations in selection and design of a screen cleaning system. A gravity system relies on differences in weight between kernels to facilitate separation.

### **OBJECTIVES**

The first objective of this investigation was to measure physical characteristics of cheat seed to provide data to design and adjust a machine that will mechanically devitalize the seeds. The second objective was to compare properties of cheat and wheat seeds to facilitate the development of a combine harvester-mounted separation system.

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

## **MATERIALS AND METHODS**

### **Physical Characteristics**

Cheat (*Bromus secalinus* L.) seeds used in these experiments were collected from screenings of combine harvested wheat (*Triticum aestivum* L.) in Oklahoma, USA. The moisture content was approximately 12%, wet basis.

<u>Dimensions</u>: The dimensions of the seeds were measured in three directions using a digital caliper gauge ( $\pm 0.01$  mm). The major diameter was the length of the seed, the intermediate diameter was the width, and the minor diameter was the thickness of the seed. The minor diameter was taken perpendicular to the intermediate diameter. The caliper was held perpendicular to the direction of the dimension being measured. Length was measured on 200 seeds, and width and thickness on 50 seeds.

<u>Sphericity and aspect ratio</u>: The sphericity index and the aspect ratio (Mohsenin, 1986) were calculated for 50 seeds. The volume of a solid is equal to the volume of a tri-axial ellipsoid with intercepts a, b, c. The sphericity index,  $S_p$ , is defined as,

$$S_p = \frac{(abc)^{0.333}}{a} x \quad 100$$
 (1)

The aspect ratio, R<sub>a</sub>, was calculated as follows:

$$R_a = \frac{b}{a} \tag{2}$$

<sup>5</sup> 

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

<u>Weight</u>: The number of seeds in twenty samples weighing approximately 0.5 g was determined by manually counting and recording weight per 1000 seeds.

<u>Bulk density</u>: The bulk density of cheat seed was determined on 10 samples. Cheat seeds were poured into a cylindrical can (72.2 mm inside diameter by 108.7 mm depth) and weighed on a digital top-loading balance. The bulk density was computed by dividing the average measured weight by the computed volume of the cylinder.

#### **Aerodynamic Properties**

<u>Terminal velocity</u>: The terminal velocity, or critical velocity, of cheat seeds was measured on fifty samples. A vertical air tunnel made from a plexiglass tube (L > 10D) and a hot wire anemometer were used to determine terminal velocity (Mohsenin, 1986). The apparatus is shown in figure 2. For each of the 50 samples, two or three cheat seeds were randomly selected from a population of 500g of cheat seeds. There were placed on a mesh screen in the bottom of the vertical tube. Input air was adjusted with a slide gate until the seeds began to float. The velocity at which all the particles became suspended was measured with a hot wire anemometer VelociCalc Model 8357 (TSI Inc., St Paul, MN) through small holes (10D from the screen) in the tube wall.

<u>Drag coefficient</u>: The drag coefficient of cheat seed was calculated from the measured terminal velocity using the equation below (Mohsenin, 1986):

$$C = \frac{2W(\mathbf{r}_p - \mathbf{r}_f)}{V_t^2 A_p \mathbf{r}_p \mathbf{r}_f}$$
(3)

6

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

# **RESULTS AND DISCUSSION**

#### **Physical Characteristics**

Dimensions: The frequency distributions for length, width, and thickness were approximately normally distributed. The cheat seeds averaged 6.85 mm long, 1.35 mm wide, and 1.24 mm thick which agrees with Grochowicz (1980) (Table 1). The standard deviations were 0.44, 0.12, and 0.12 respectively. The coefficients of variation were 6.5%, 8.9%, and 9.9% respectively. Cheat seeds were longer and thinner than wheat seeds which have a 6.02 mm length, 1.79 mm width, and 2.54 mm thickness with 6.8%, 13.3%, and 3.1% coefficients of variation respectively (Stroshine, 1994). The differences in dimensions between cheat and wheat are important in selecting screens (size and shape of holes) to separate cheat from wheat.

The width and the thickness of the cheat seed are important in setting the gap between the rolls to crush or crimp the seeds. During the tests run to mechanically damage cheat seeds with the roller mill, the gap between the rolls was varied from 0.1 mm to 1.1 mm. As expected, the damage was greater with smaller roll gaps (Hauhouot et al., 1998). Cheat seed dimensions are also essential in choosing the appropriate screen size for the hammer mill. Hammer mill screen sizes of 3.18 mm (8/64 in.), 3.97 mm (10/64 in.), and 4.76 mm (3/16 in.) successfully devitalized cheat by mechanically damaging the seed, without the need for complete grinding.

Sphericity and aspect ratio: Sphericity is an expression of the shape of a solid relative to that of a sphere of the same volume while the aspect ratio relates the width to the length of the seed which is indicative of its tendency toward being oblong in shape (Omobuwajo et al. 1999). Cheat seeds had a sphericity index of 32.12% and an aspect ratio of 19.26% compared to 58.04% and 46.35% for wheat kernels (Table 1). Cheat seeds cannot be treated as a sphere for analytical calculations because of their low sphericity index. Moreover, the low aspect ratio (19.26%)

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

shows that cheat seeds are oblong in shape and will not roll easily. They will tend to slide on their flat side, unlike wheat kernels that can roll. This information is important in the design of hoppers, separation and conveying equipment.

<u>Weight</u>: The weight of 1000 cheat seeds was 5.0 g with a standard deviation of 0.18, compared to 40.0 g for the same number of wheat seeds (Table 1). Wheat kernels are generally 8-10 times heavier than cheat. Moreover the specific gravity of cheat seed ranged from 0.3 to 0.4 compared to 1.2 - 1.5 for wheat (Grochowicz, 1980). Therefore, gravity separation could likely be used to separate these two materials.

<u>Bulk density</u>: The bulk density of the cheat was  $210 \text{ kg/m}^3$  compared to the reported  $230 \text{ kg/m}^3$  (Grochowicz 1980). The standard deviation was 0.01 and the range between 0.20 and 0.22. The reported wheat bulk density of 772 kg/m<sup>3</sup> (Stroshine, 1994) shows that wheat is 3.4 to 3.7 times more dense than cheat, data that are useful in bin design.

#### **Aerodynamic Properties**

<u>Terminal velocity</u>: Measured terminal velocities for cheat seeds ranged from 1.8 to 4.5 m/s, with a mean of 3.14 m/s and a standard deviation of 0.82. Measured terminal velocity for wheat had a mean of 7.84 m/s and a standard deviation of 0.91. The range was from 5.8 to 9.8 m/s. This is lower than the 8.9 m/s to 11.5 m/s range reported by Grochowicz (1980). The ranges of terminal velocity for cheat and wheat do not overlap. Consequently, aerodynamic separation is theoretically possible. A terminal velocity of 5.5 m/s was selected to test a multiple stage aspirator for a combine harvester mounted wheat separator. A summary of aerodynamic properties including the experimental results and referenced data are shown in table 2.

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

<u>Drag coefficient</u>: Drag coefficients, needed in design calculations to describe aerodynamic properties, were calculated from the experimental terminal velocities. The drag coefficient for wheat was calculated as 0.74, based on the average experimental terminal velocity. Likewise the experimental drag coefficient for cheat was 1.05.

### CONCLUSIONS

Cheat seeds were 6.85 mm long, 1.35 mm wide, and 1.24 mm thick whereas wheat seeds were being 6.02 mm long, 2.79 mm wide, and 2.54 mm thick. The sphericity index of cheat seeds was 32.12% compared to 58.04% for wheat seeds. The aspect ratio was 19.26% compared to 46.3% for wheat. The average weight of 1000 cheat seeds was 5.0 g compared to 40.0 g for wheat. The bulk density of cheat was 210 kg/m<sup>3</sup> compared to 772 kg/m<sup>3</sup> for wheat. Separation of cheat from wheat seeds is not likely based on length but is possible based on seed width, thickness, and density.

Cheat seeds had an average terminal velocity of 3.14 m/s and a standard deviation of 0.82, compared to an average of 7.84 m/s and standard deviation of 0.91 for wheat. Thus, the drag coefficient was 1.05 for cheat seed compared to 0.74 for wheat. There is a considerable difference between terminal velocities of cheat and wheat seed, which suggests that aerodynamic separation of cheat and wheat is possible.

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

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<sup>10</sup> 

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

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Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

	$Mean value \pm S.d$ (Minimum Maximum)		
		(Willing and a second s	,
Properties	Cheat (Experimental)	Cheat (Reported)"	Wheat (Reported)§
Length (10 <sup>-3</sup> m)	$\begin{array}{c} 6.85 \pm 0.44 \\ 5.70 \ \_ 8.05 \end{array}$	6.0 _ 8.40	$6.02 \pm 0.41$
Width (10 <sup>-3</sup> m)	$\frac{1.35 \pm 0.12}{1.07 \ \_ \ 1.71}$	1.40 _ 2.40	$2.79\pm0.37$
Thickness (10 <sup>-3</sup> m)	$\begin{array}{c} 6.85 \pm 0.44 \\ 5.70 \ \_ 8.05 \end{array}$	1.20 _ 2.0	$2.54\pm0.08$
Geometric mean (10 <sup>-3</sup> m)	$2.21\pm0.14$	-	3.49
Sphericity index (%)	$32.12\pm2.29$	-	58.04
Aspect ratio (%)	$19.26 \pm 2.15$	-	46.35
Weight of 1000 seeds (g)	$5.0 \pm 0.18$ $4.61 \pm 5.31$	5.0	40.0
Bulk density (kg/m <sup>3</sup> )	$\begin{array}{c} 210\pm0.01\\ 200\ \_\ 220 \end{array}$	230	772

#### Table 1-Physical characteristics of cheat and wheat seed

S.d Standard deviation

Data from Grochowicz.(1980). pp.42-44 Table 3.6Data from Stroshine (1994) pp.11 Table 2.1

Table 2-Aerodynamic properties of cheat and wheat seed.				
	Mean value ± S.d (Minimum _ Maximum)			
Material	Terminal velocity (m/s)	Drag coefficient		
Cheat (Experimental)	3.14 ± 0.82 1.79 _ 4.46	1.05 0.52 _ 3.4		
Wheat (Experimental)	$\begin{array}{c} 7.84 \pm 0.91 \\ 5.79 \_ 9.81 \end{array}$	0.74 0.47 _ 1.36		
Wheat (Reported)…	8.9 _ 11.5	0.34_0.58		

S.d Standard deviation

" Data from Grochowicz.(1980). pp.42-44 Table 3.6

<sup>12</sup> 

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.



Figure 1. Open floret of cheat (Bromus secalinus L.)





Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.

# NOTATION

- a major axial dimension of seed (m)
- b intermediate axial dimension of seed (m)
- c minor axial dimension of seed (m)
- $R_a$  aspect ratio (%)
- S<sub>p</sub> Sphericity index (%)
- W mass of particle (kg)
- $\rho_p$  mass density of the particle (kg/m<sup>3</sup>)
- $\rho_f$  mass density of the air (kg/m<sup>3</sup>) at 21°C from Table 9.2. Mohsenin (1986)
- Vt terminal velocity (m/s)
- $A_p$  projected area normal to the direction of motion (m<sup>2</sup>) with  $A_p = (\pi / 4) ab$ .
- C drag coefficient (dimensionless)

Hauhouot-O'Hara M., B.R. Criner, G.H. Brusewitz, and J.B. Solie. July 2000. "Selected Physical Characteristics and Aerodynamic Properties of Cheat Seed for the Separation from Wheat". Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II.